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STRUCTURE AND EVOLUTION OF THE LARGE SCALE GRANULATION FLOW PATTERN

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A granulation movie has been performed at the Pic du Midi Observatory on September, 20, 1988. It combines spatial resolution (close to the diffraction limit of the 50cm refractor at 5750 Å : 0"23), a large field of view (100"x70") and a duration of 3 hours. The movie was digitized with a 1024x1024 CCD camera at Lockheed Palo Alto Research Laboratory (LPARL). The images were compressed to 512x512 frames to be processed with movie processing developped at NSO Sunspot and LPARL (November et al., 1986 ; Title et al., 1986, 1988, Simon et al., 1988, Brandt et al. 1988). It consists of alignement of consecutive frames, destretching for atmospheric distorsion, and a 4km sec^{-1} subsonic filtering which removes the 5 minute oscillations. Video disk movies of the full 3 hours, as well as a 57 min segment of the best quality were assembled. Time averaged plots of the velocity vectors were made. An example is shown in Figure 1, representing the velocity pattern derived from the 57 min best segment. The motions related to the evolution of granules are suppressed by the averaging, revealing a steady flow pattern. The Pic du Midi granulation movie contains an additional important piece of information : the location of magnetic flux tubes can be detected through the identification of the associated Network Bright Points (NBPs) which form the photospheric network (Stenflo and Harvey, 1985 ; Muller, 1985). All NBPs which appeared during a period of 20 minutes are plotted in Figure 1. A single large cell, suggesting a supergranule, is prominent in the right side of the plot. The accumulation of NBPs at the boundary supports the supergranule nature of this cell.

Many regions of divergence are visible within the cell boundaries, which can be considered to be mesogranules (Simon et al., 1988 ; Title et al., 1989) ; such regions are also visible outside the supergranular cell. The regions of convergence are more prominent outside the large cell than inside. Surprisingly, there is no vortex visible in the movie, although the field of view is 15 times larger and the duration 25 times longer than the La Palma movie, where such a flow pattern was discovered (Brandt et al., 1988).

Figure 1 shows where magnetic flux tubes, which produce NBPs, tend to accumulate. As we have already noticed, the main accumulation occurs at the supergranule boundaries. There are, in addition, several concentrations of NBPs in isolated convergence areas. It is also remarkable that very few magnetic features are visible inside the supergranule and that they completely avoid the centers of divergence. There is a concentration of Network

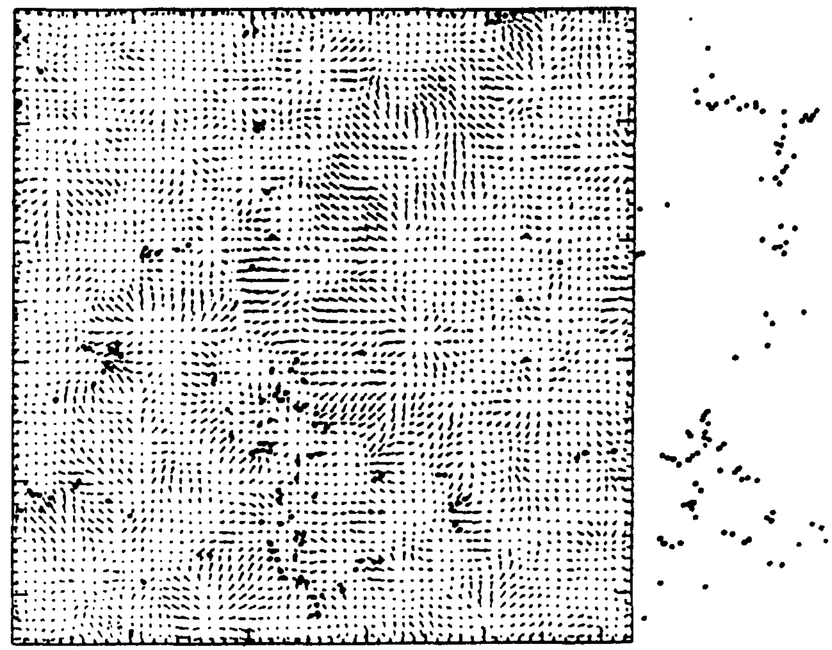

Figure 1 : Granulation flow pattern on 64x64 grid, averaged over 57 minutes. The position of the Network Bright Points (NBPs) identified during a 20 minute segment are plotted ; many of them have been identified outside the processed area. The divisions represent 1".

Bright Points in the lower part of the field of view ; it corresponds to a region of abnormal granulation produced by the remnant of an active region or a small plage. It is interesting to note that there is a small area of divergence inside this plage, which is free of NBPs. The amplitude of the vectors is small in the plage area, which is compressed between large amplitude inward flows ; they probably contribute to stabilize the plage area.

Figure 2 is a 33 minute time average of the flow pattern. It was derived from the 3-hour movie and represents a slightly different area than in Figure 1 ; its dimension is 58"x48". Five successive frames were produced in order to analyse the change of the flow pattern. The supergranule is stable over the 3-hour duration of the movie. The divergence areas are noted as overlayed contour maps of the average flow vectors ; their position is shown at the beginning and at the end of the sequence. Their motion toward the supergranular boundary is evident, especially when they are located away from the cell center. The translational velocities range from 0.0 km/s to 0.7km/s, with a mean velocity of 0.3 - 0.4 km/s ; this is consistent with the horizontal velocities derived in supergranules from Dopplergrams. Asymmetry in the granular flow pattern also suggests a mesogranular flow to the boundary of the

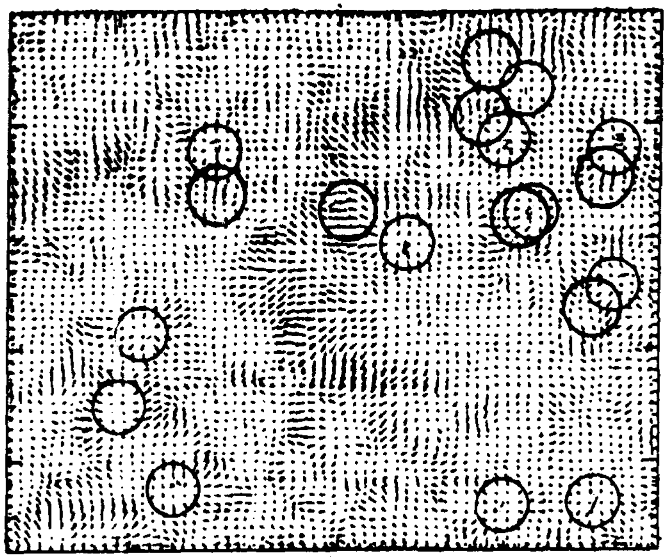

Figure 2 : Granulation flow pattern on a 64x64 grid, averaged over 33 minutes. Initial positions of divergence regions are marked by a thin circle ; their positions 2.5 hours later are marked by a thick circle.

supergranular structure. Velocity arrows are longer on one side of the mesogranules, indicating motion in that direction : the supergranular flow sweeps the mesogranular cells to its boundary. There are 7 to 8 diverging regions in the supergranule cell at any time. One of these regions will appear or disappear every 33 minutes, which implies a mesogranule lifetime of about 3 hours. Outside the supergranule, the diverging regions move at random and their lifetime is shorter, two hours in average.

Our observational results about the flows on the surface of the sun are in good agreement with the predictions of the 3-D numerical simulation of solar convection, recently performed by Stein and Nordlund (1989). They describe the horizontal flow in terms of a hierarchy of cell sizes ; pressure fluctuations induced by large scale cells can reach the surface, driving horizontal flows which in turn advect smaller cells.

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